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The Application of Thermoelectric Conversion Module in the Temperature Detection

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Abstract: Through the analysis of the phenomenon of large operation equipment heat failure, it is put forward in the paper that use the semiconductor temperature sensor converted the signal of temperature difference into weak voltage combined with controlled boost DC-DC converter circuit to provide power to ultra-low-power temperature measurement circuit controlled by single chip microcomputer and output the temperature measurement information in the form of infrared modulation signal. Focused on solving the thermal power modules in semiconductor output voltage instability, small pressure differential, DC-DC converters start of the ultra-low-voltage problems, combined with the practical application of the environment at the scene of an independent power supply and temperature measurement devices, as well as the composition of the work carried out Further explore. *Copyright © 2013 IFSA.*

Keywords: Heat Defect, Temperature Difference Sensor, Boost Circuit, DC-DC.

1 Introduction

Heat release of the power equipment under operation is a potential threat to the secure operation of power system. Based on comparative analysis, we find that the heating phenomenon in the actual operation of substation equipment is easily appeared in large current loop connection if the running way changed, great load changed or the temperature is high. An electrical equipment external defect diagnosis criterion is shown in Table 1 [1].

The use of a thermal power semiconductor technology without field power supply or battery supply to provide power for the temperature measurement circuit and control circuit [2] under the high-temperature high-pressure is put forward in the design scheme. The temperature measurement circuit can be started when the temperature difference caused by heat is higher than 10 K, otherwise it is unplugged and wait. Taking full advantage of the low power modes of single-chip temperature measurement circuit combined with intermittent work to finish data acquisition and processing is achieved, and isolation between primary equipment temperature measurement of high voltage power and the testing of secondary equipment is successfully implemented, which assures system's safety and reliability.

Table 1. Electrical equipment external heat defect diagnosis criteria.

Type	Generally	Serious	Emergency
Temperature increase range	10-20	20-40	≥40
Temperature range	50-60	60-80	≥80

2. The Temperature Measurement Scheme and Principles

As is shown in Fig. 1, the temperature measuring device based on low-power AVR single chip microcomputer comprises DC power circuit, voltage stabilizing circuit and temperature alarm circuit. DC power generation module uses a thermal power semiconductor module to produce a direct current. The output voltage of the thermal power semiconductor module is produced by the temperature difference between hot layer and hot layer of the thermal power semiconductor module. The instable output voltage caused by unfixed temperature difference does not satisfy the requirement of the temperature measurement circuit. In order to provide the temperature measurement circuit with a stabilized voltage supply, firstly boost and regulate the voltage. If the temperature difference of 15 K is supplied to a thermal power semiconductor module of 40×40 mm^2 with 126 couples of PN junctions, about 0.6 V (higher than actuation voltage of ultra-low charge pump) open circuit voltage is created. Through the low voltage charge pump, can start the DC-DC controller and feed the output of 3.3 V, 200 mA to subsequent temperature measurement circuit. The principle and process of the modules are analyzed as below.

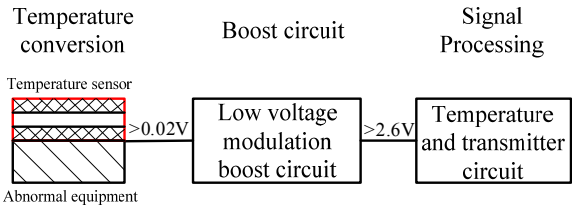

Fig. 1. Diagram of temperature measurement program.

3. Power Circuit

The thermal power semiconductor module generates electricity mainly by temperature difference between cold and hot layers, there are two issues of crucial importance: sources of heat and lowering the temperature of the cold layer. Raising temperature difference is key to the generate electricity device [3]. According to the actual temperature measurement requirements, select the heating part (wiring row)of the electrical equipment as heating source on the hot layer, install radiator and the fan drove by the thermal power semiconductor module on the cold layer. The semiconductor thermoelectric generator installation is shown in Fig. 1. The temperature will come to 313 K~373 K which is initiated by wiring row overheated. In order to transfer heat generated by the heating element as efficient as possible to the thermal power semiconductor module, we put one side of the installation plate in direct contact with the heating element and take the other side close to the hot layer of the thermal power semiconductor module. At the same time the gap between installation plate and the hot layer is coated with silica gel which vents the gas and makes the module surface be thoroughly exposed to the installation plate. In this way, the heat transfer efficiency is effectively improved. The cold layer and radiator are coated with silica, and the fan working on 1.5 V is fixed on the radiator. Starting and stopping the fans controlled by the single chip microcomputer fixes the temperature of the cold layer under 333 K.

Relation between open circuit voltage and temperature difference is shown in Fig. 2. According to the relation curve, temperature difference of 1 K breeds 0.04 V. The relation between matching output power and temperature difference like Fig. 3 when the two sides of the thermal power semiconductor module are matched resistors. As is shown 1 K temperature difference generate 0.0045 W of power. In the system, when the temperature difference between the hot and cold layers is less than 40 K, the output power is supplied only to the temperature measurement circuit, or else fans work to lower temperature of the cold layer and the output voltage of the thermal power semiconductor module is about 1.6 V, some part of the energy is used to drive fans and the other part is useful in the temperature measurement circuit.

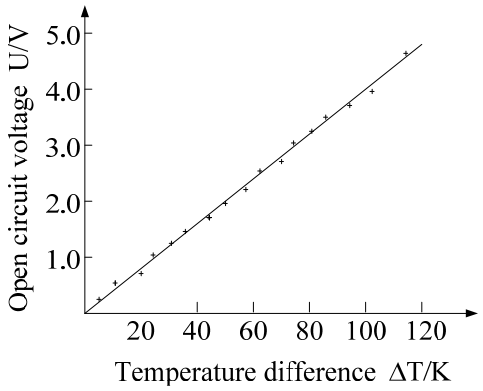

Fig. 2. Relation between open circuit voltage and temperature difference.

4. Voltage Stabilizing Circuit

The biggest problems existing in the thermal power modules in semiconductor is output voltage instable, smaller the temperature is, lower the output voltage is. The Fig. 3 shows that when the temperature difference between the hot and cold layers is less than 25 K, the open circuit output voltage is less than 1 V. To guarantee the subsequent circuit will work normally, power supply voltage must be greater than 2.6 V, usually we tend to adopt step-up charge pump DC-DC conversion [4]. The

minimum input voltage of the traditional charge pump is between 0.9 V and 1.0 V, and the minimum input voltage of step-up DC/DC conversion is also about 1.0 V (starting voltage range from 0.6 V to 0.7 V). If the input voltage has dropped below 0.6 V, the traditional charge pump or internal DC/DC conversion circuit (such as the oscillator, the error-amplifier, the logical circuit, electronic switch, etc.) does not work, so the traditional booster device cannot achieve the goal of booster when input voltage is less than 0.6 V.

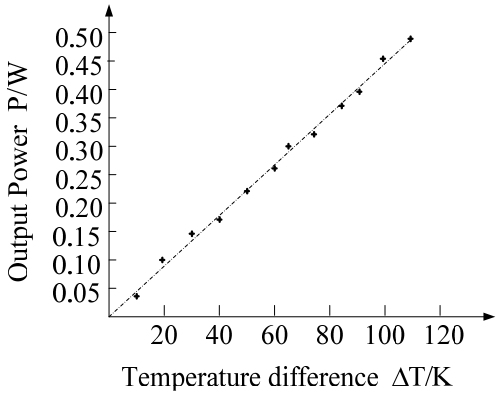

Fig. 3. Relation between matching output power and temperature difference.

In the boost control circuit shown in Fig. 4, we choose audio step-up transformer TS_AUDIO_100_TO_1 [5] of which the set-up ratio is 100:1. At the ambient temperature of 25 °C, when hands of 37 °C touch the hot layer of the thermal power semiconductor module, the output voltage of the thermal power semiconductor module is 0.02 V, as the output of MCU the square-wave signal of 0.6 V / 100 HZ is the control signal of the Q1's gate, that are the contents of test condition.

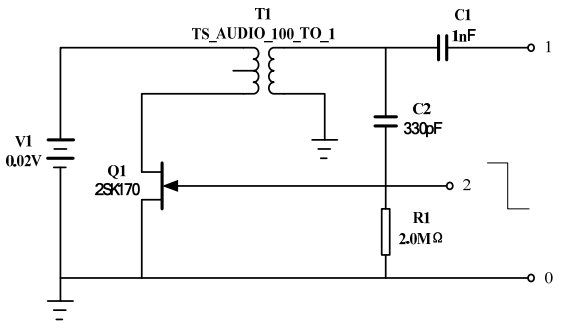

Fig. 4. Boost DC / DC converter circuit.

The output 2.5 V / 100 Hz square-wave signal of the booster modulation conversion circuit, the phase of which differs by 180 degrees from the phase of control signals on both ends, commutated and stabilized by the subsequent circuit and provides the power supply to the system, as is shown in Fig. 5.

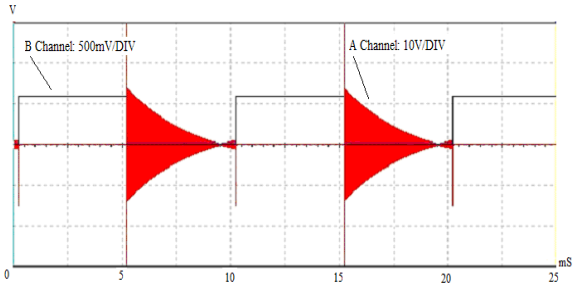

Fig. 5. Boost modulation circuit simulation results.

5 Temperature Alarm Circuit

The design uses a low-power AVR single chip microcomputer and 1-wire bus digital thermometer combined with infrared LED tubes which compose temperature alarm circuit. Select the ATmega8L single chip microcomputer as controller, DS18B20 temperature sensor is used to measure temperature, alarm light emitting diode use GP1303CA infrared light emitting diode LED the circuit is shown in Fig. 6.

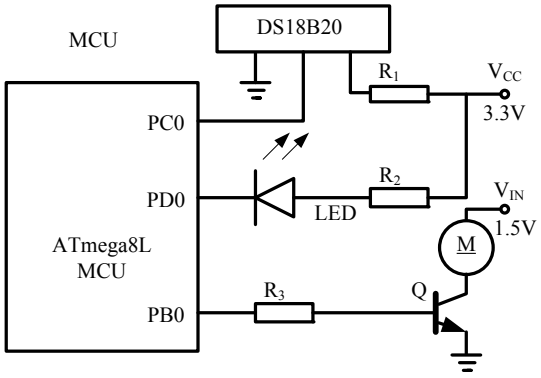

Fig. 6. Single-chip microcomputer temperature.

ATmega8L MCU [6] which is particularly suitable for low-power operation environment has five hibernation modes, the operating voltage is 2.7 V - 5.5 V, idle mode power consumption at frequency of 4MHz is 1 mA (3 V, 25 °C), Power-On-Reset circuit and Brown-out-detection circuit are integrated in its internal .

DS18B20 sensor [7] of which the operating voltage is 3.0 V - 5.5 V, measurable rang of the temperature is -55 °C - +125 °C, the resolution is 9-12-position adjustable, minimum temperature resolution is 0.0625 °C, the accuracy range is -10 °C-+85 °C, output interface is a digital signal and 1-Wire bus. Sealed by stainless steel tube plays the role of waterproof and anti-corrosion.

Cooling fans is specific customizable. Water-proof electric motor SRE-300-14270 of which the

working voltage is 0.5 V - 4 V（nominal voltage is 1.9 V), on-load current is 32 mA, the maximum power output is 0.42W. When the temperature of heating parts reach 330 k, CPU connects the switch tube Q through port PB0(active-high), to ensure that the temperature difference between cold and hot layers as large as possible the fans directly supplied by The thermal power semiconductor module which cool The thermal power semiconductor module simultaneously. Result of debugged actually shows: the thermal power semiconductor module's 1.8 Voutput voltage, 100 mA output current and 80 mA total load current consumption meet the demands of system working normally. With temperature increasing, the output power of the thermal power semiconductor module and the cooling effect of the fan increase, tests show that in the case of fans working, the temperature of the cold layer is forced to 340 K.

GP1303CA infrared light LED is made of GaAs [8], the central wavelength is 940 nm which is in the sensitive spectral range of CCD camera with night vision capability; radiation intensity is 10 mw/sr, power is 150 mW (If=20 mA), the camera can record the infrared imagery at a range of 150 m drives. The LED twinkling is drove by CPU at different frequency based on the difference between heating temperature and the ambient temperature, according to whether the temperature overrun and different temperature. The twinkling signal is accepted and processed by the on-site camera. The relation between temperature difference and blinking frequency is listed in Table 2.

Table 2. Relation between temperature difference and twinkling frequency.

Temperature (K)	≤15	≥15	≥40	≥60	≥80	≥100
frequency （HZ）	dull	0.1	0.2	0.5	2	light

6 Terminal Works

When the heating temperature of monitored equipment is 12 K higher than ambient temperature, the thermal power semiconductor module produces output voltage ended up being 0.5 V and the set-up DC/DC converter TPS61201 provides the temperature measurement circuit stable voltage around 3.3 V. Then, ATmega8L single chip microcomputer moves from the state of power off into conducting position, and the terminal program is activated. Make sure that communication protocol and all ports are initialized, temperature sensor is connected properly, write the temperature threshold to TH/TL, read the identification code of the temperature sensor before use. when it starts, ATmega8L single chip microcomputer sends periodic temperature conversion instruction to temperature sensor DS18B20, DS18B20 automatically compares the temperature value with the trigger threshold of TH/TL registers, set the warning mark if the temperature value is higher than the threshold of TH or lower than the threshold of TL. Then, the CPU read the temperature and the warning flag at the same time, CPU drives infrared LED flashing alarm at different frequencies according to whether the temperature overrun and different temperature, Infrared light signal alarm is accepted and processed by the surveillance cameras. Temperature flow chart is shown in Fig. 7.

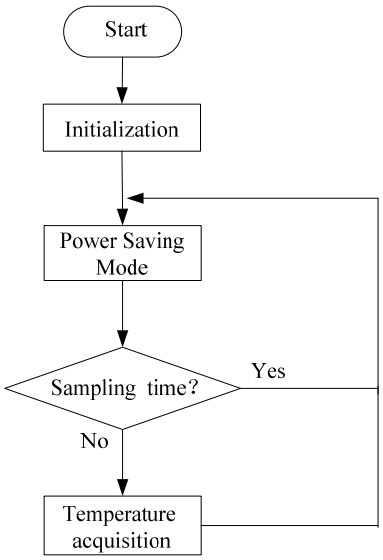

Fig. 7. Temperature flow chart.

The Brown-out Detection on ATmega8L tests a change of V_{cc} when the voltage supplied by set-up DC / DC converter is lower than minimum operating voltage of ATmega8L (ATmega8L< 2.7V; DS18B20 < 1.6 V). The trigger level is set to 2.7 V (BODLEVEL unprogrammed) or 4.0 V (BODLEVEL programmed). It will reset itself and be in a power down standby state when the power off occurred in operation, the trigger level of BOD has hysteresis eliminating the power peak. When the input voltage of TPS61201 converter is below 0.3 V, the output power is shut down and latched. The power supply can auto instauration work when the input voltage is higher than 0.4 V, then ATmega8L single chip microcomputer re-energize from the power wait state into working condition.

7. Conclusions

This temperature detection terminal, of which the peripheral equipment is simple, is supplied by heat source site, low-power consumption and wireless transmission, which applies to heat defect real time

supervision without supplying or using battery to provide power.

Acknowledgment

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